TECHNICAL REPORT 159

AIR WEATHER SERVICE

ESTIMATES OF ALTITUDES WITH SPECIFIED PROBABILITIES OF BEING ABOVE ALL CLOUDS

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PREFACE

This report presents military planners, design engineers, and AWS personnel who support their activities, with estimates of the probability of being above all clouds during selected months over the Northern Hemisphere.

The report is concerned with the long-range, or strategic planning aspects of environmental support to a system or operation. Such information can be used in establishing design of equipment, feasibility of operation, advanced operational plans, etc. The short-range, or tactical support would be provided by routine forecasts.

The method which forms the basis of the results contained in this report is documented in the literature. Estimates of values of various unobserved cloud parameters can be made as a logical outgrowth of the basic method.

I wish to thank Captain Kenneth V. Heuer for his aid in acquiring the necessary data for this study and in analyzing the charts.

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16 October 1961

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ESTIMATES OF ALTITUDES WITH SPECIFIED PROBABILITIES OF BEING ABOVE ALL CLOUDS

SECTION A – INTRODUCTION

This report presents the results of developmental efforts by the Climatic Center, USAF, toward a graphical method for estimating the probabilities of being above all clouds. Such information is useful to various Air Force and other governmental planning agencies and is not available in other known sources. The quantitative results provided are designed as a basic planning tool for long-range purposes.

SECTION B – DISCUSSION

The accompanying charts, Figures 1 through 16, show for the Northern Hemisphere altitudes above which the probabilities of less than one-tenth sky coverage are 95%, 90%, 80%, and 60%. Charts are presented for the midseason months January, April, July, and October.

These estimates are based on an extension of a method which was originated in the Climatic Center, USAF [1]. The basic method is a graphical procedure for estimating frequencies of ceilings (six-tenths or more clouds) within various altitude ranges. It employs standard ceiling data to an altitude of 10,000 feet, frequencies of six-tenths or more total sky cover, and mean tropopause height. These data were analyzed as objectively as possible, but considerable subjectivity was sometimes necessary. Further development of the original method [2] indicated that, for stations in varying geographical locations, cumulative frequency curves for various cloud amounts paralleled the curve for six-tenths or more cloudiness. Thus, having a cumulative frequency curve of ceiling occurrence versus height and knowing the total frequency of "ceilings" defined by a cloud amount other than six-tenths or more, we can estimate the cumulative frequency versus height curve for that total cloud amount. It is this type of curve, applied to one-tenth or more cloudiness, which is the basis of the estimates.

A basic parameter used in this study is the mean seasonal tropopause height, which is assumed to be the maximum altitude for cloud formation. Although this assumption is not strictly true, there are insufficient data on cloud height-tropopause relationships to provide the basis for an improved estimate of the heights of tops of high clouds. Monthly, rather than seasonal, tropopause heights would have been more appropriate, to conform with the monthly cloud data used; but this information was not available for an adequate sample of stations.

A series of atlases published by the US Navy [3] contains distributions of tropopause heights over the oceans by seasons, hence, adjustments on a monthly basis could not be made. Data based on jet aircraft observations indicate that some clouds are observed above the tropopause, but rather infrequently and usually within a few thousand feet of tropopause levels. Therefore, the assumption of the lack of clouds above the

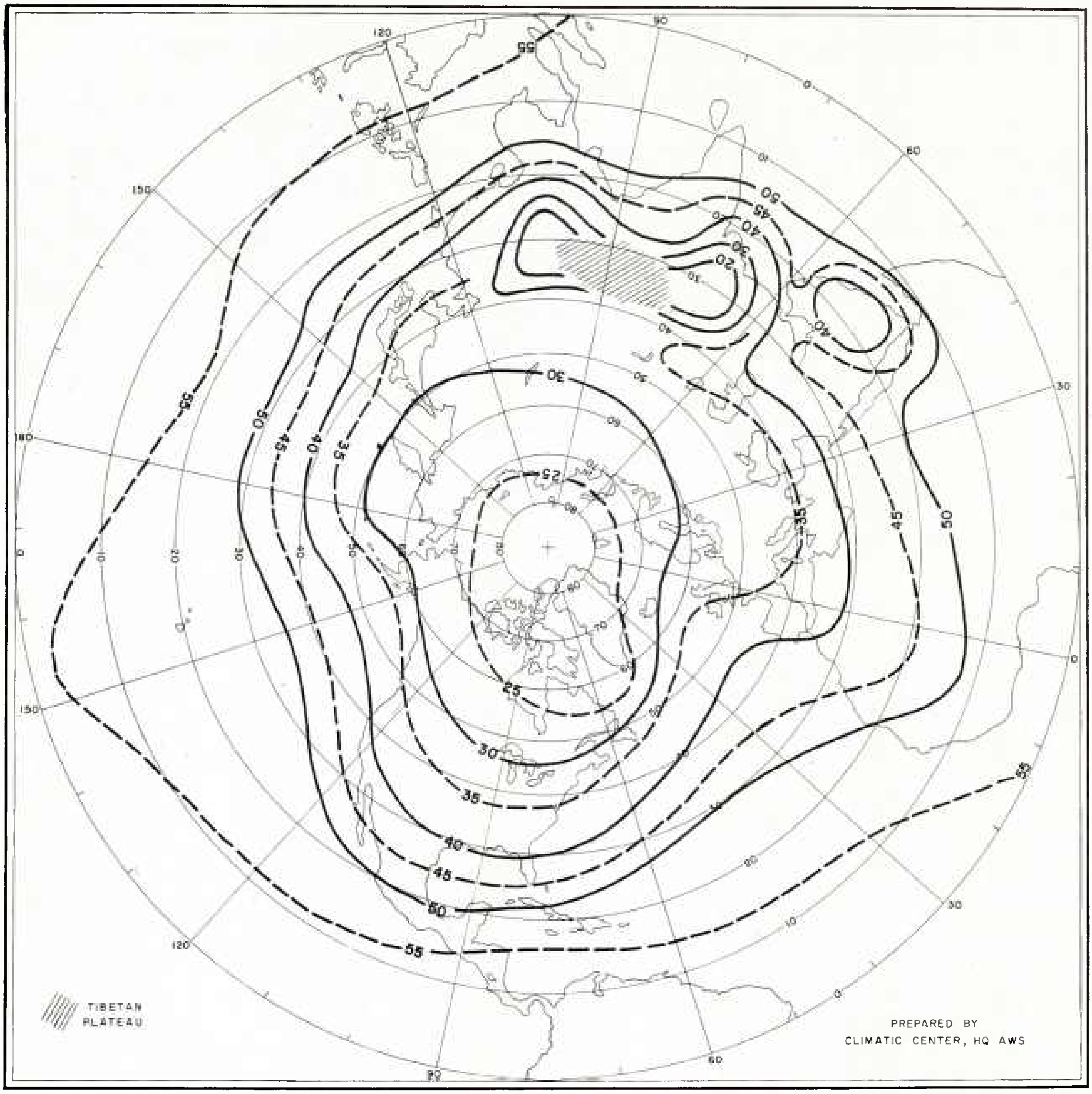

FIGURE 1. . ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 95% PROBABILITY OF HAVING < 1/10 SKY COVER
JANUARY

tropopause should not affect materially the estimates shown in the accompanying charts. Also, indications are that cirrus tops are usually close to the tropopause when the tropopause is low, and farther below the tropopause with increasing tropopause height. This factor would tend to minimize the possible error in using mean tropopause heights rather than the nonexistent ideal data on the joint variations of cloud and tropopause heights.

Attempts were made to evaluate the validity of the results contained in Figures 1 through 16 by comparing them with data accumulated from special high-altitude aircraft observation programs [4] [5] [6] [7]. Unfortunately, quantitative comparisons could not be

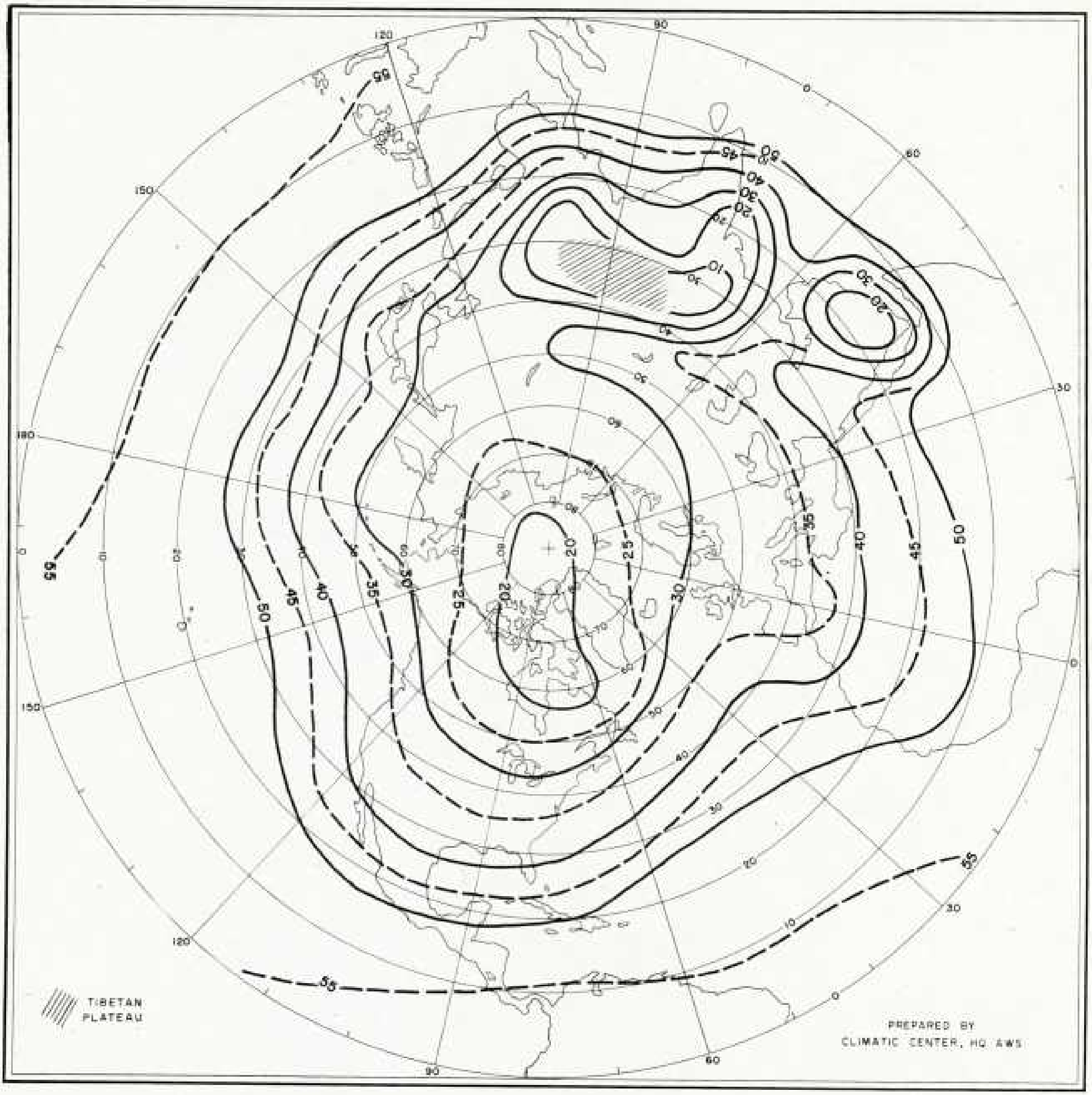

FIGURE 2. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 90% PROBABILITY OF HAVING < 1/10 SKY COVER
JANUARY

made because these data were not strictly compatible with the probability-height estimates of this study. These reports usually contained frequencies and heights of cirrus over large geographical areas. The sets of data were consistent, however, in a relative sense; i.e., increases in monthly or seasonal frequencies and heights of cirrus were in agreement in the comparisons made, and the derived values of this study were compatible with the summarized observations.

The analyses shown in the accompanying figures are based on estimated altitudes for being practically above all clouds at the various probability levels. The estimates were made for 94 stations distributed throughout the Northern Hemisphere which

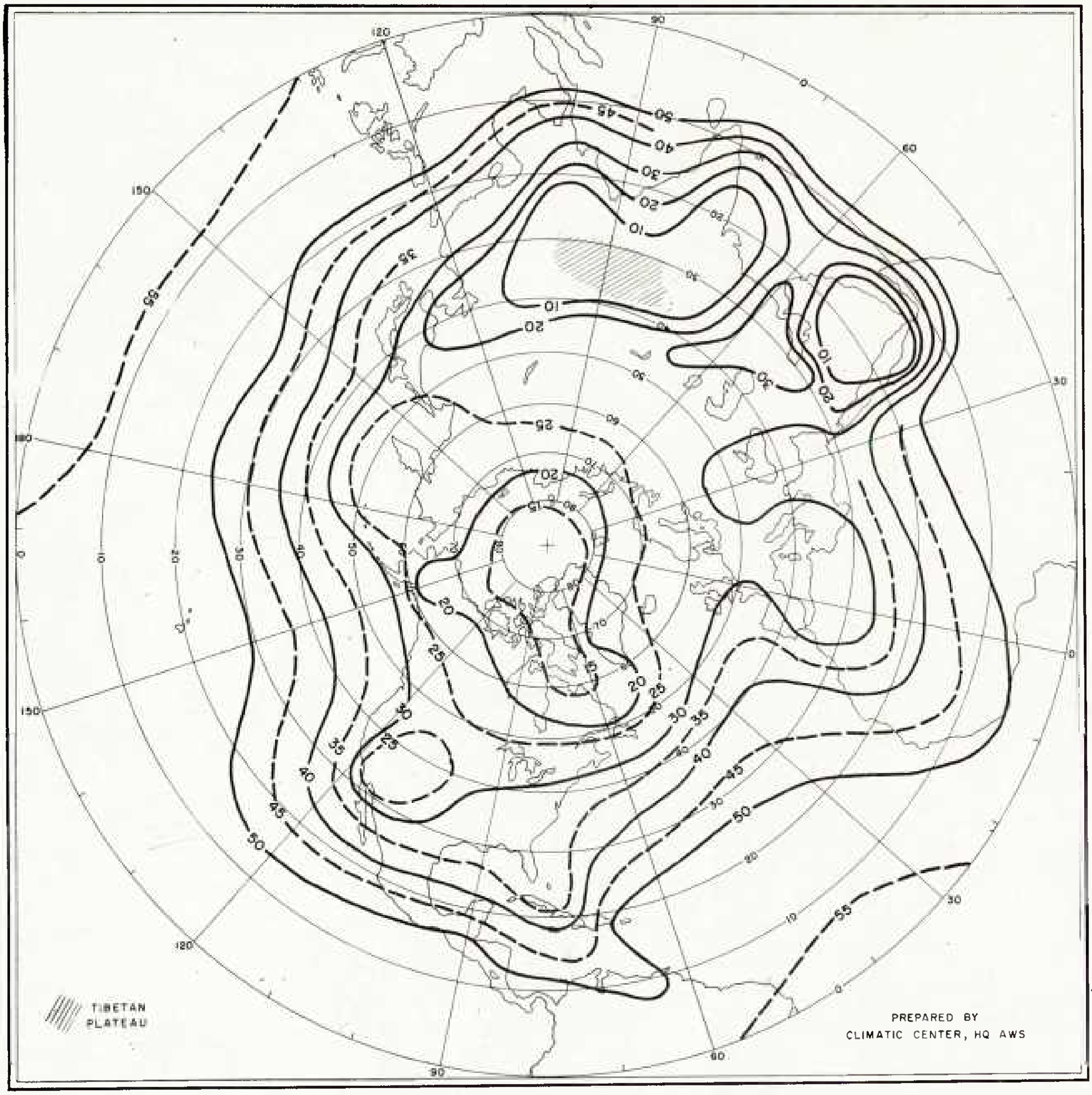

FIGURE 3. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 80% PROBABILITY OF HAVING < 1/10 SKY COVER
JANUARY

represent all major climatic regimes. Standard data available for each station were adequate for the purposes of this study. The resulting set of charts is internally consistent and is considered to be in reasonably good agreement with the limited quantitative data available.

Further work is contemplated on the problem of estimating cloud probabilities, amounts, and heights. The accompanying charts will be re-evaluated when sufficient data on cirrus heights relative to the tropopause become available.

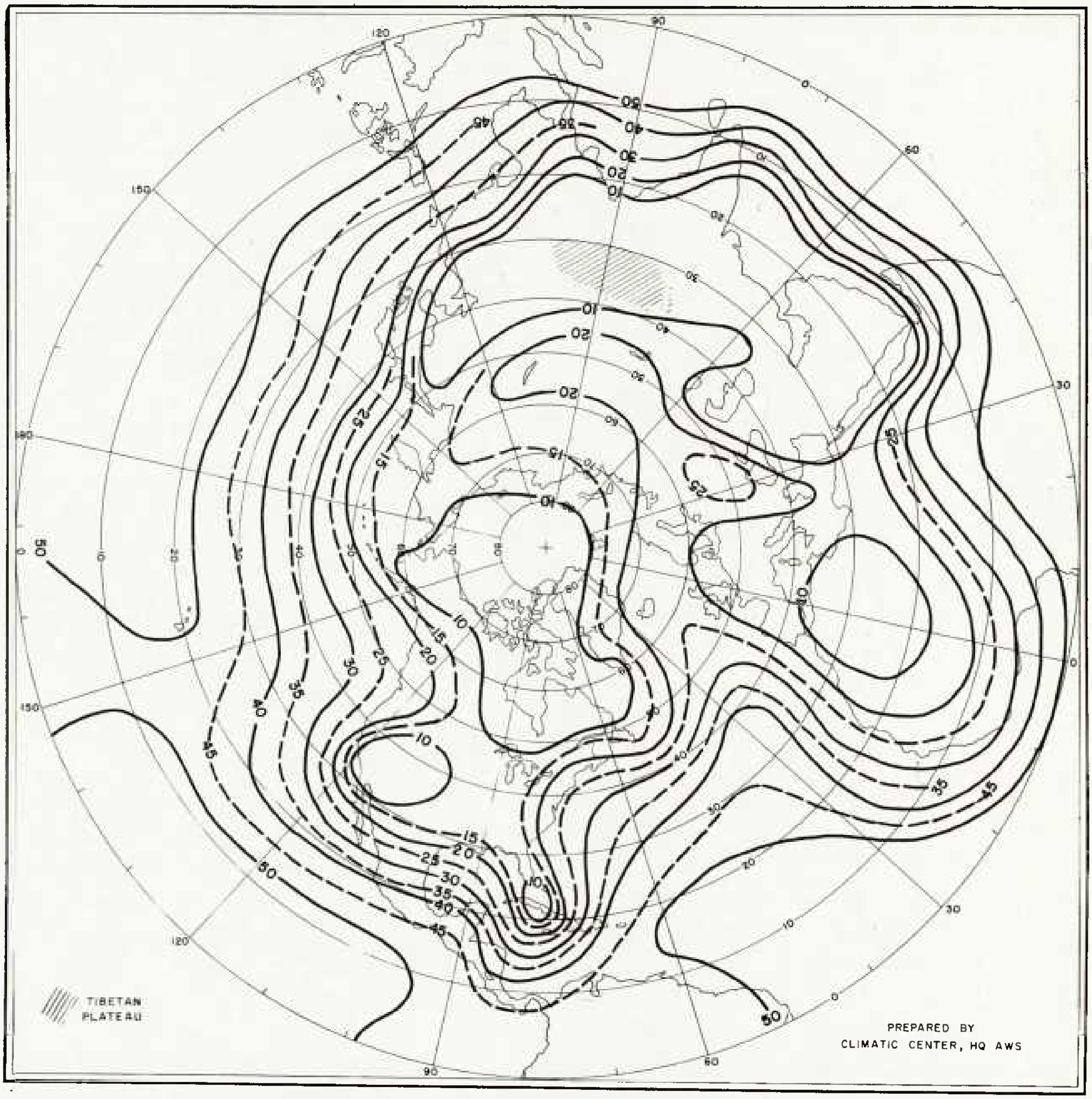

FIGURE 4. . ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 60% PROBABILITY OF HAVING $< 1/10$ SKY COVER
JANUARY

Although the charts are presented for the four midseason months (January, April, July, and October), the four specified probability levels, and the criterion of less than one-tenth sky cover, similar studies can be accomplished for other combinations of months, probabilities, and amounts of sky cover. But it is felt that the reliability of the estimates would decrease markedly for probabilities greater than 95% and for altitudes below 5000 feet.

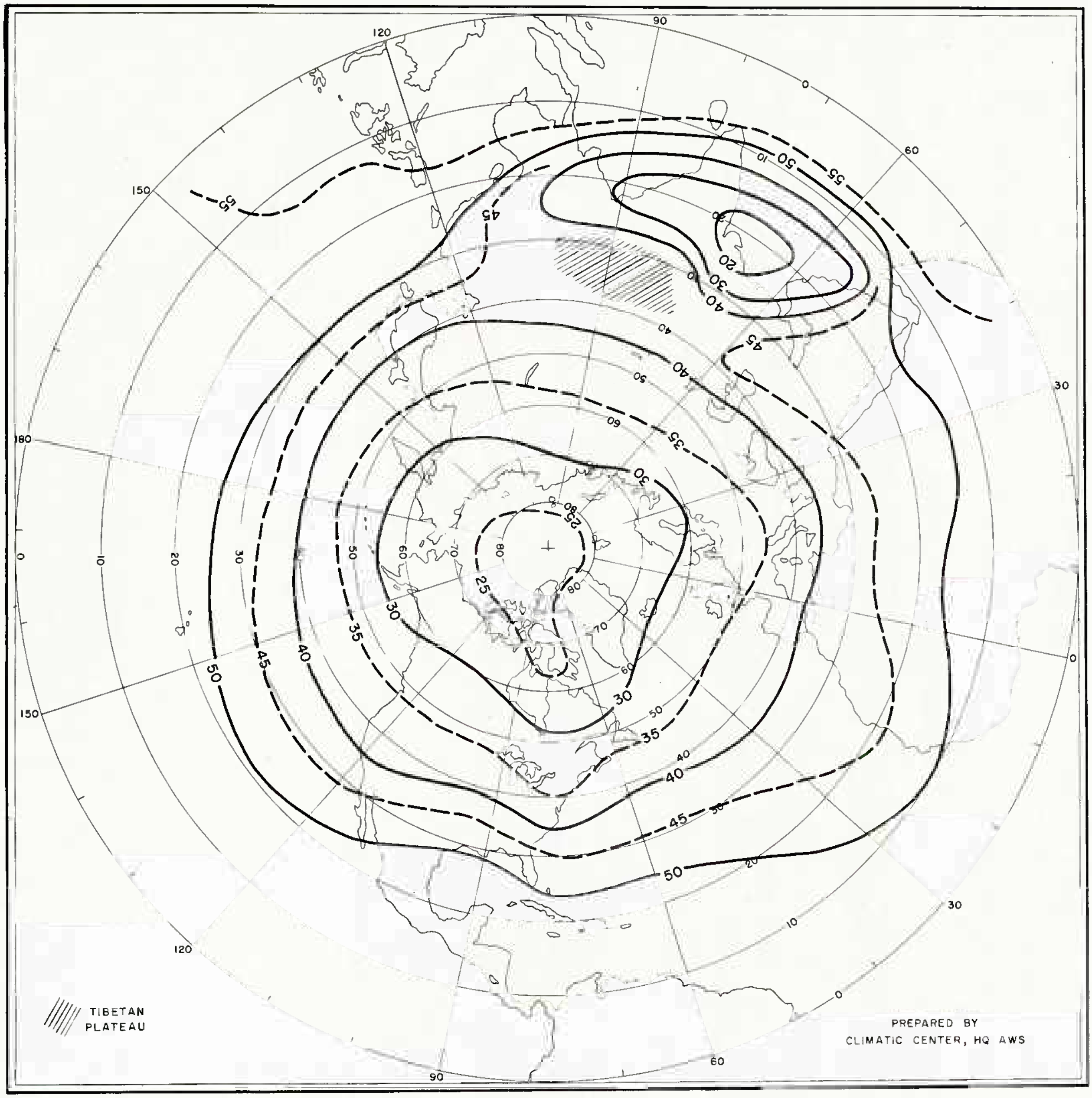

FIGURE 5. . ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 95% PROBABILITY OF HAVING < 1/10 SKY COVER
APRIL

SECTION C – APPLICATIONS

The information shown can be used to assess the feasibility of employing various detection devices, such as infrared and visual optical systems, which cannot "see" through clouds. The criterion of less than one-tenth sky cover (actually less than five one-hundredths sky cover) can be taken as essentially no interference by clouds. The selection of a probability level (95%, 90%, 80%, or 60%, as shown in the charts) for no interference by clouds depends on the calculated risk that can be tolerated in an operation.

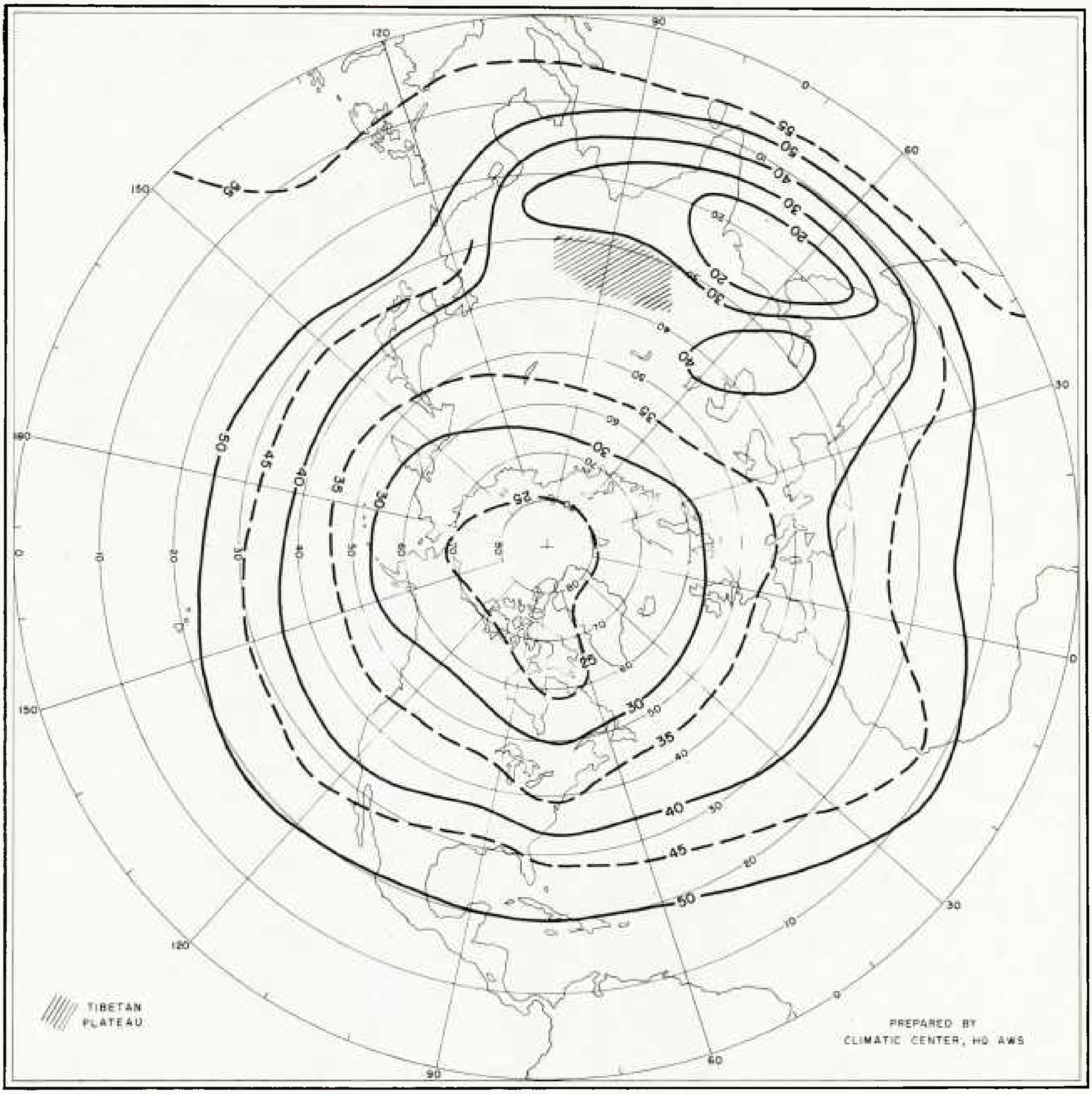

FIGURE 6. . ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 90% PROBABILITY OF HAVING < 1/10 SKY COVER
APRIL

These charts can also be used in the planning stages for certain types of operations. They will suggest a basis for selecting altitudes at which detection devices should be employed in order to have a specified probability of detecting a target within fairly short ranges. Estimating the degradation of capabilities at lower operational altitudes is another application. Values of other parameters (i.e., spatial correlations of clouds and curvature of the earth) may have to be estimated or computed to yield reliable planning data involving long path lengths. Such aspects of the problem are beyond the scope of this report.

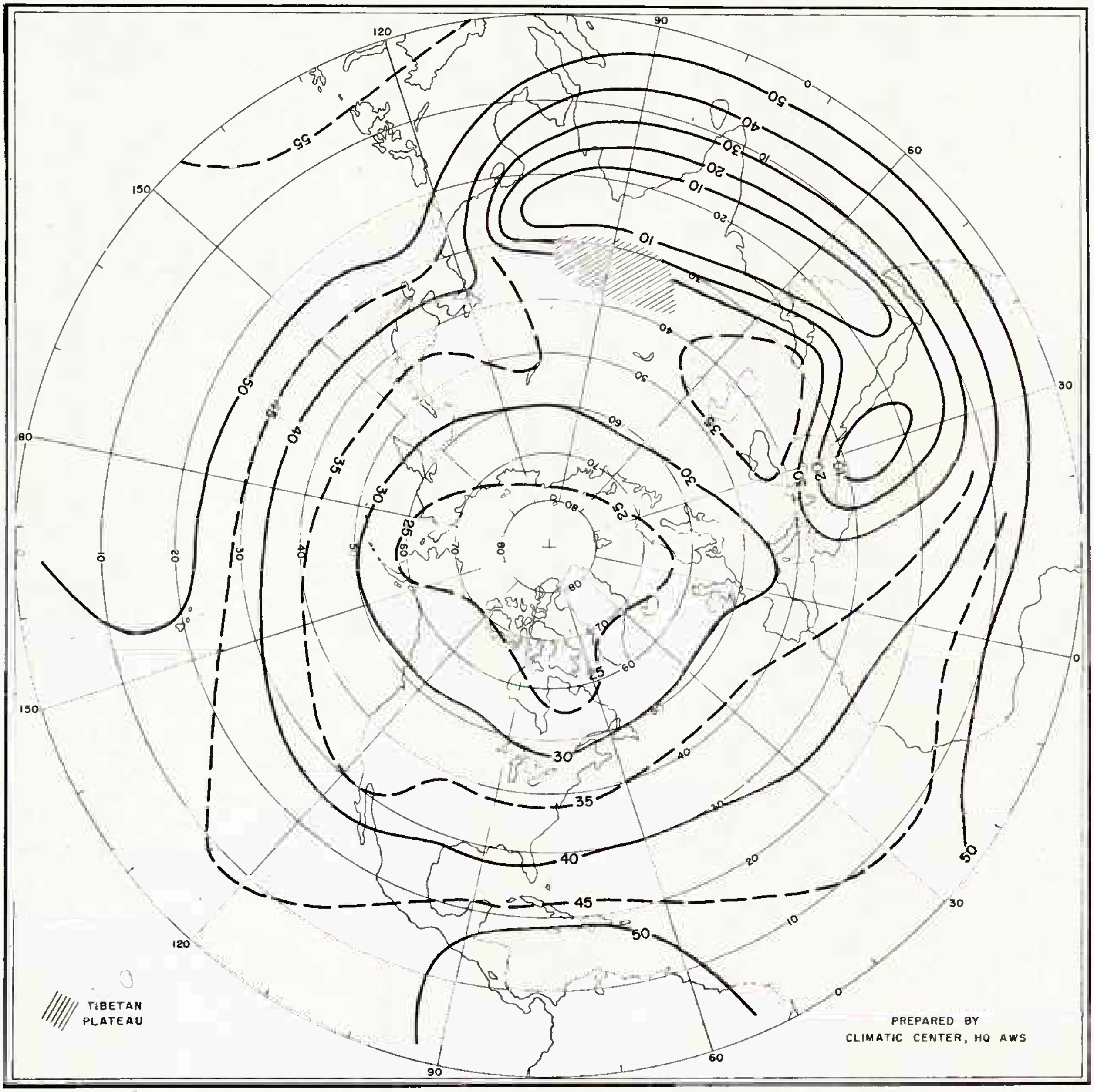

FIGURE 7. . ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 80% PROBABILITY OF HAVING < 1/10 SKY COVER
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SECTION D — RECOMMENDATIONS

It is recommended that these derived estimates be used provisionally for planning operations which are affected by the presence of clouds above normal operational altitudes. These estimates are subject to change as additional data on cloud-tropopause relationships and tropopause height variations become available. Information on spatial correlations of clouds will permit wider applicability of the charts. However, such

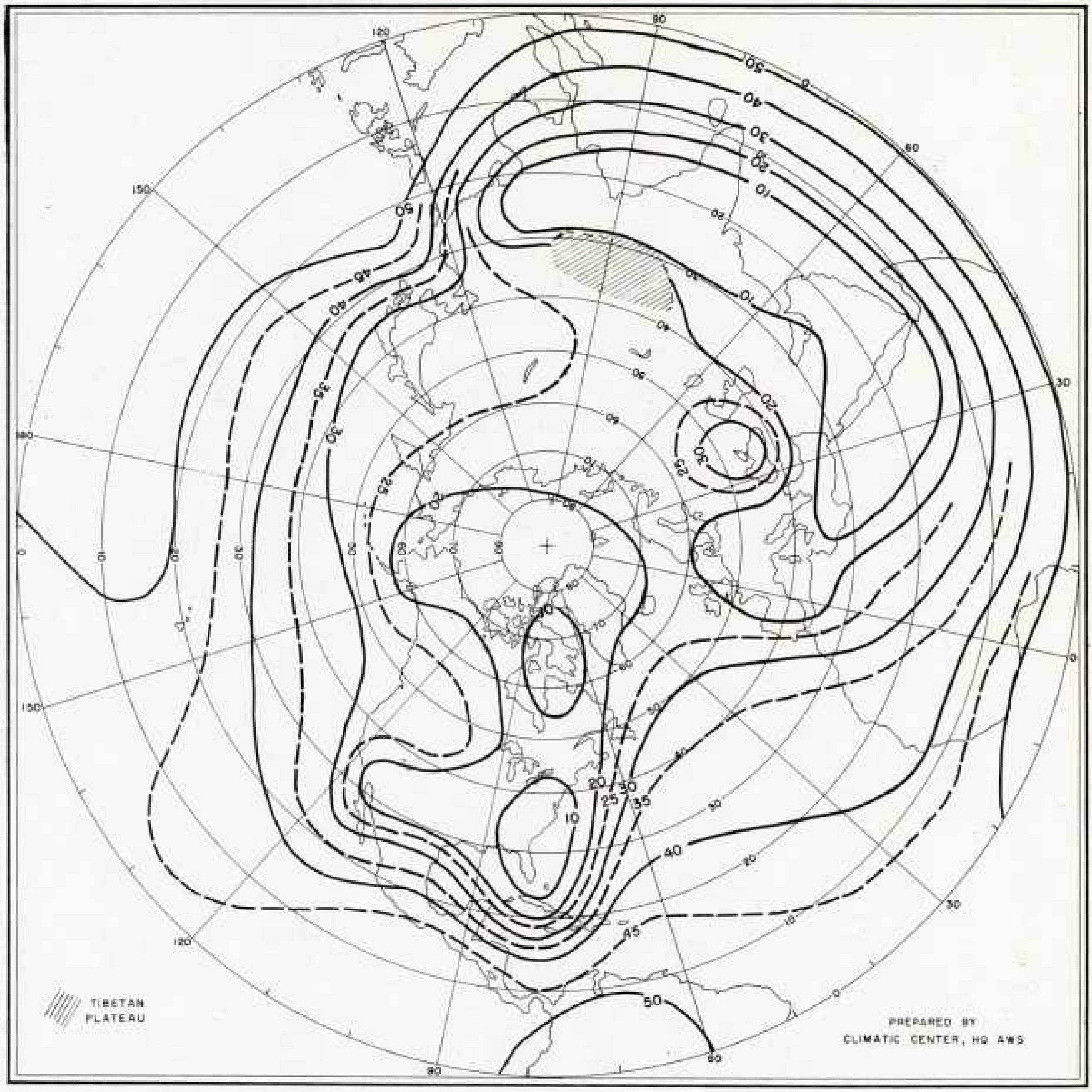

FIGURE 8. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 60% PROBABILITY OF HAVING < 1/10 SKY COVER
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data are not expected to become available in the near future. In the meantime, these estimates may be considered as reasonably accurate for use in planning those operations to which they are applicable.

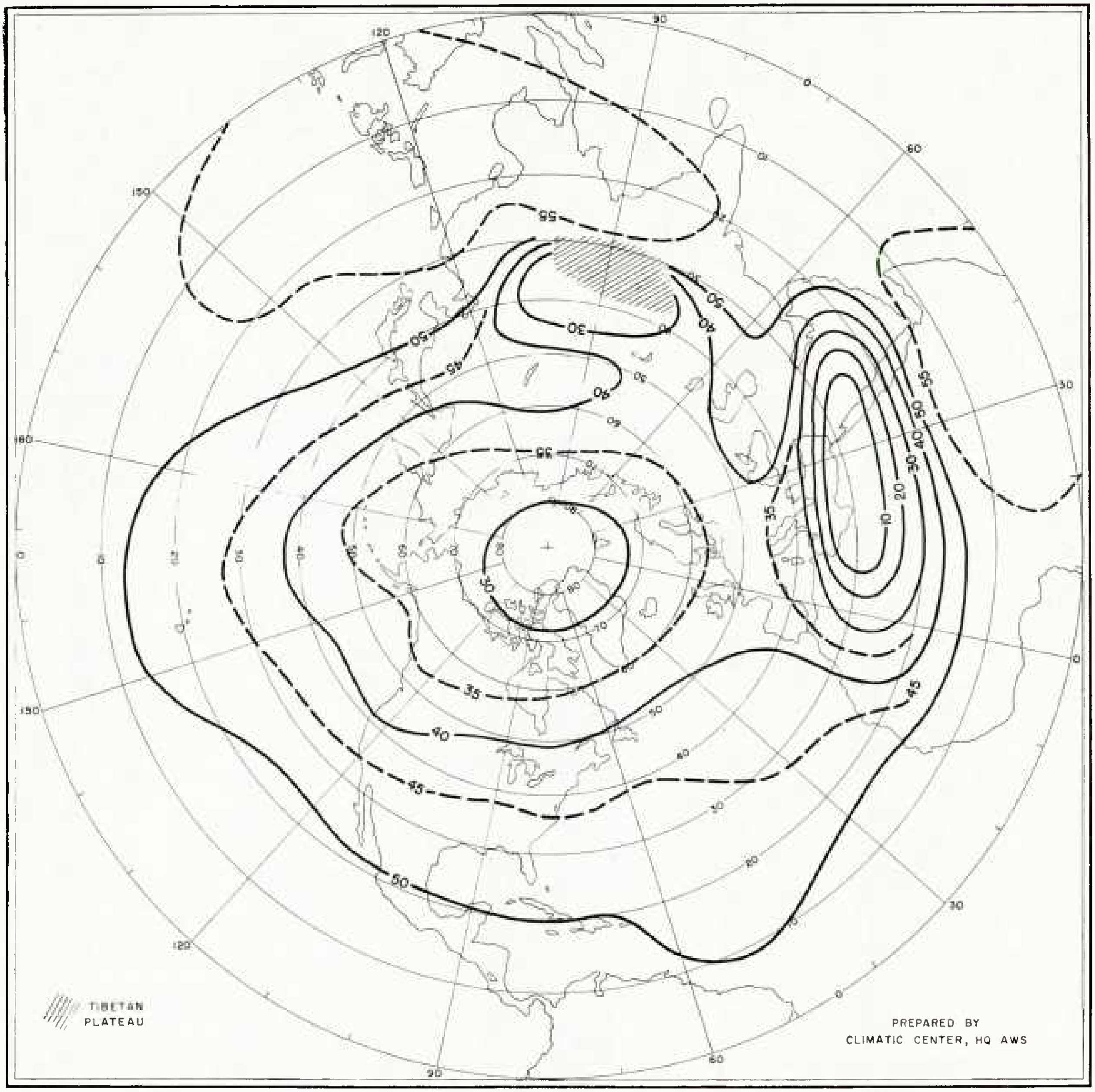

FIGURE 9. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 95% PROBABILITY OF HAVING <1/10 SKY COVER
JULY

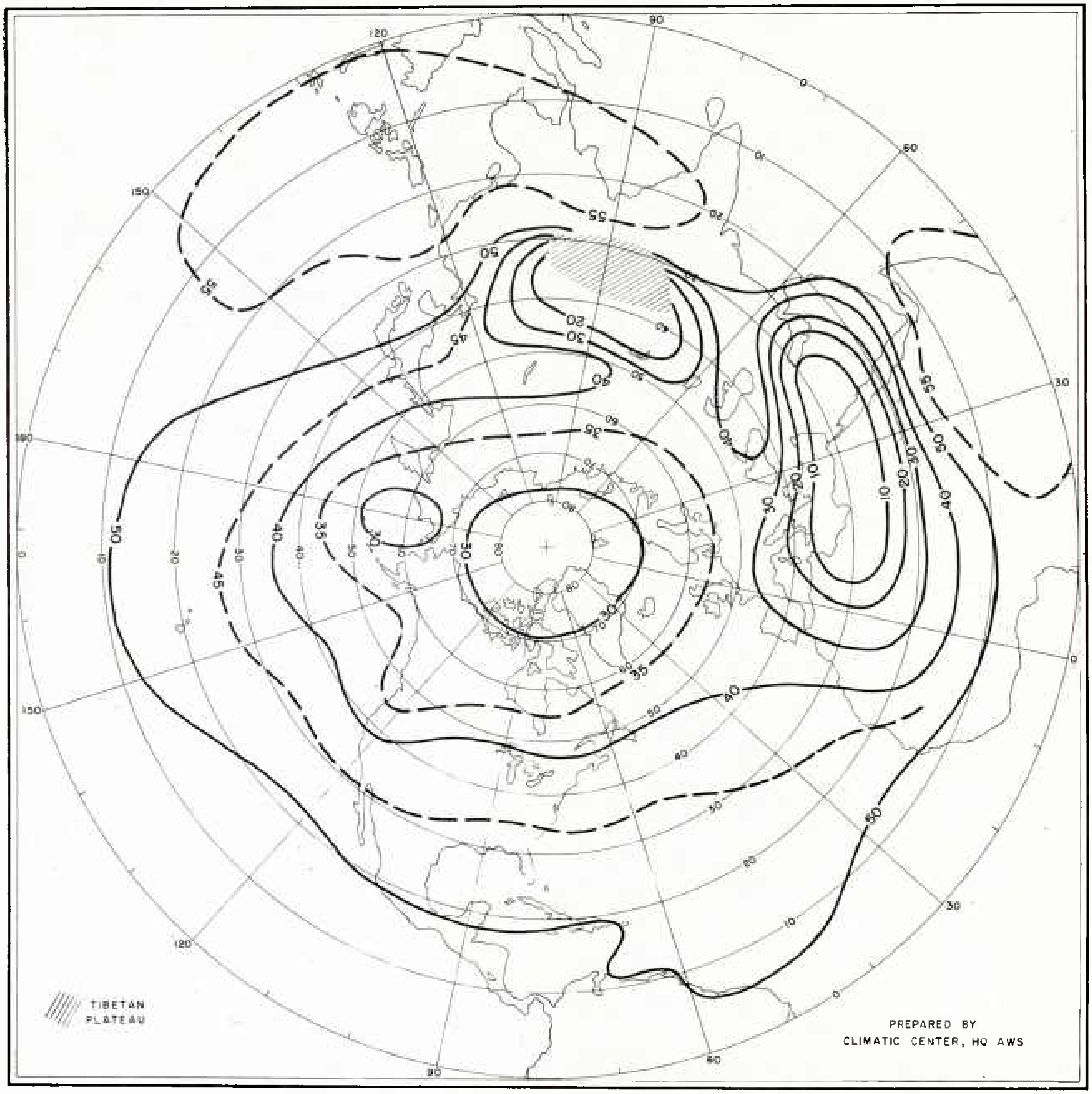

FIGURE 10.. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 90% PROBABILITY OF HAVING < 1/10 SKY COVER
JULY

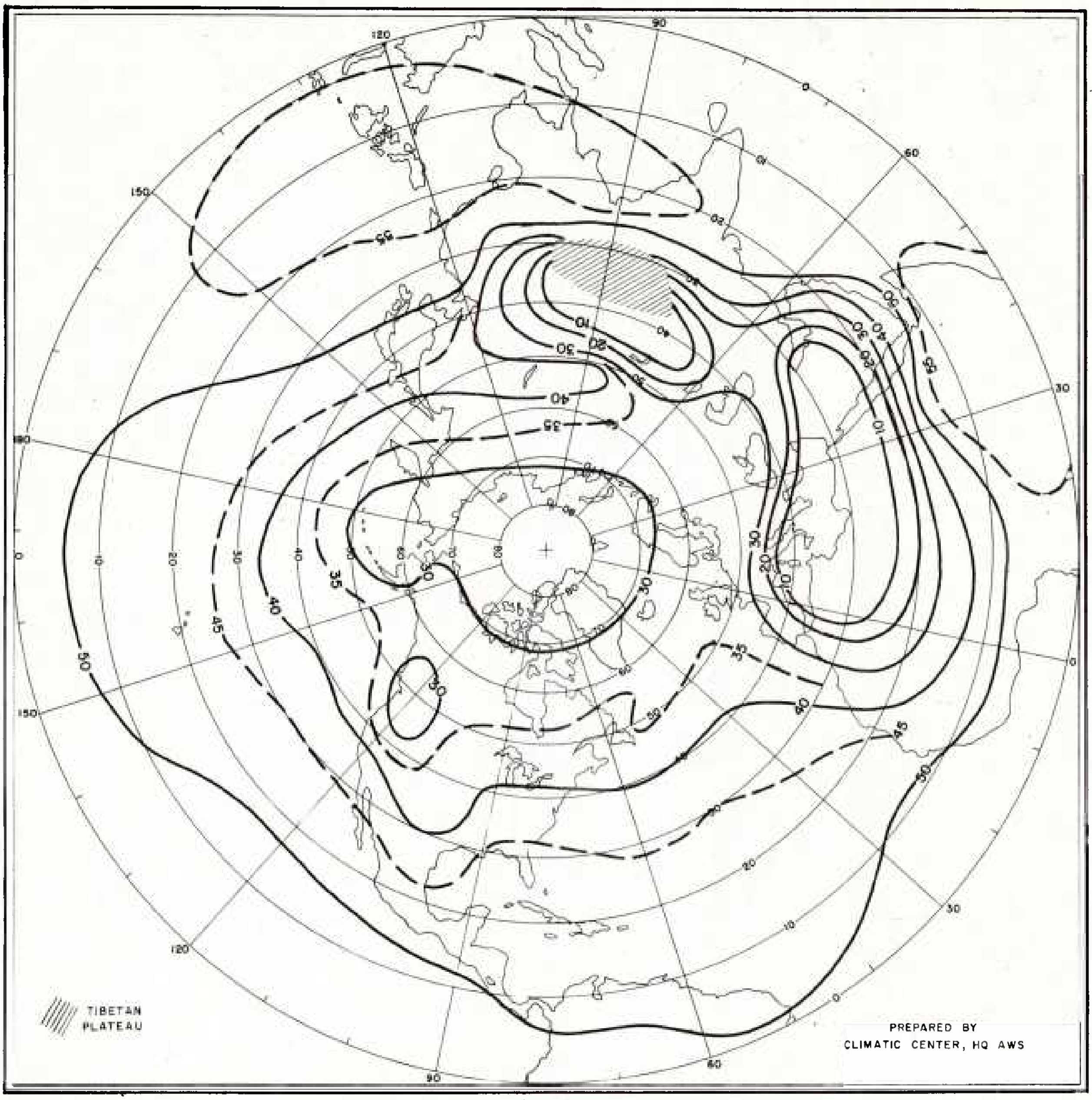

FIGURE 11. . ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 80% PROBABILITY OF HAVING < 1/10 SKY COVER
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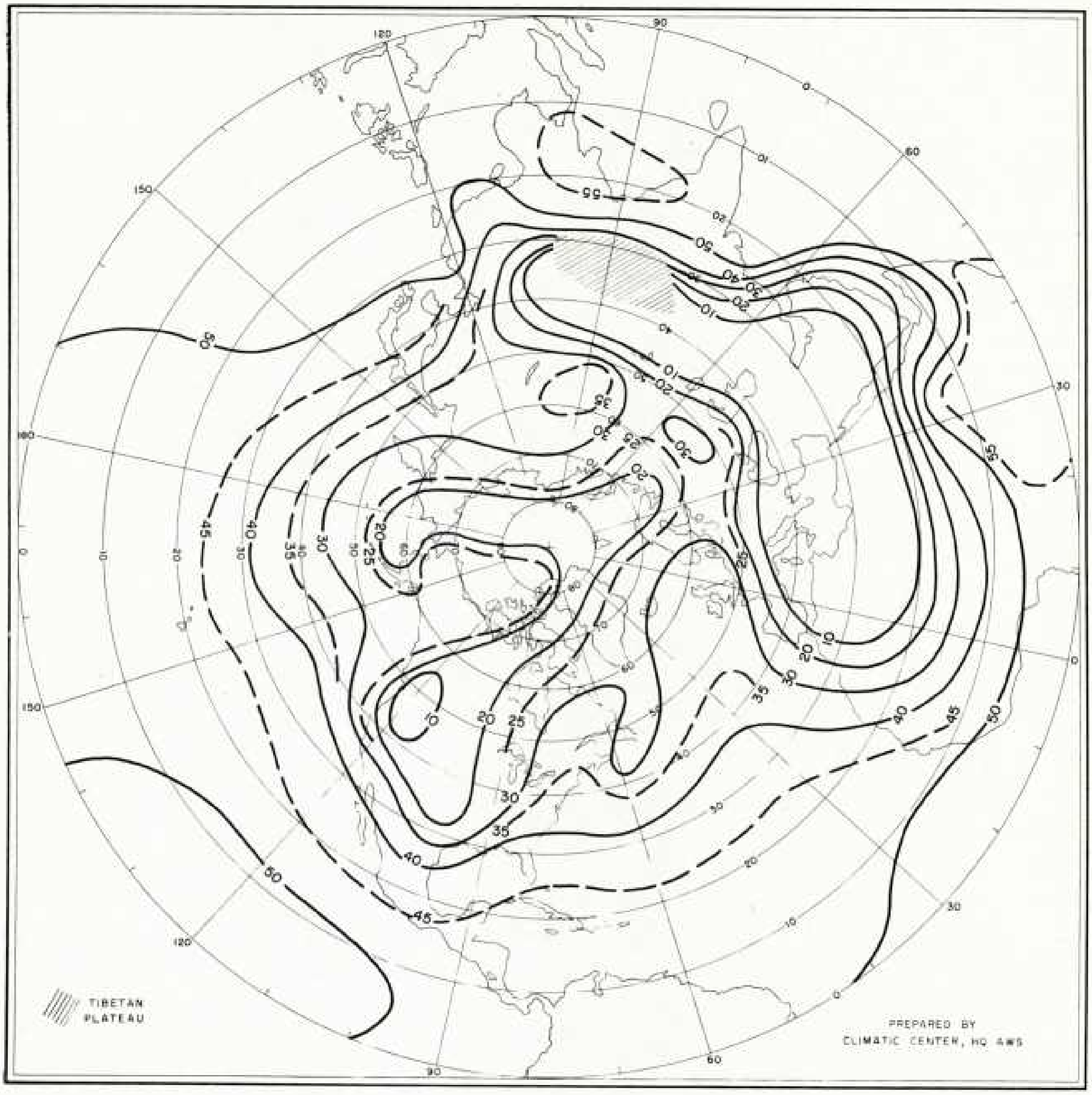

FIGURE 12. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 60% PROBABILITY OF HAVING < 1/10 SKY COVER

JULY

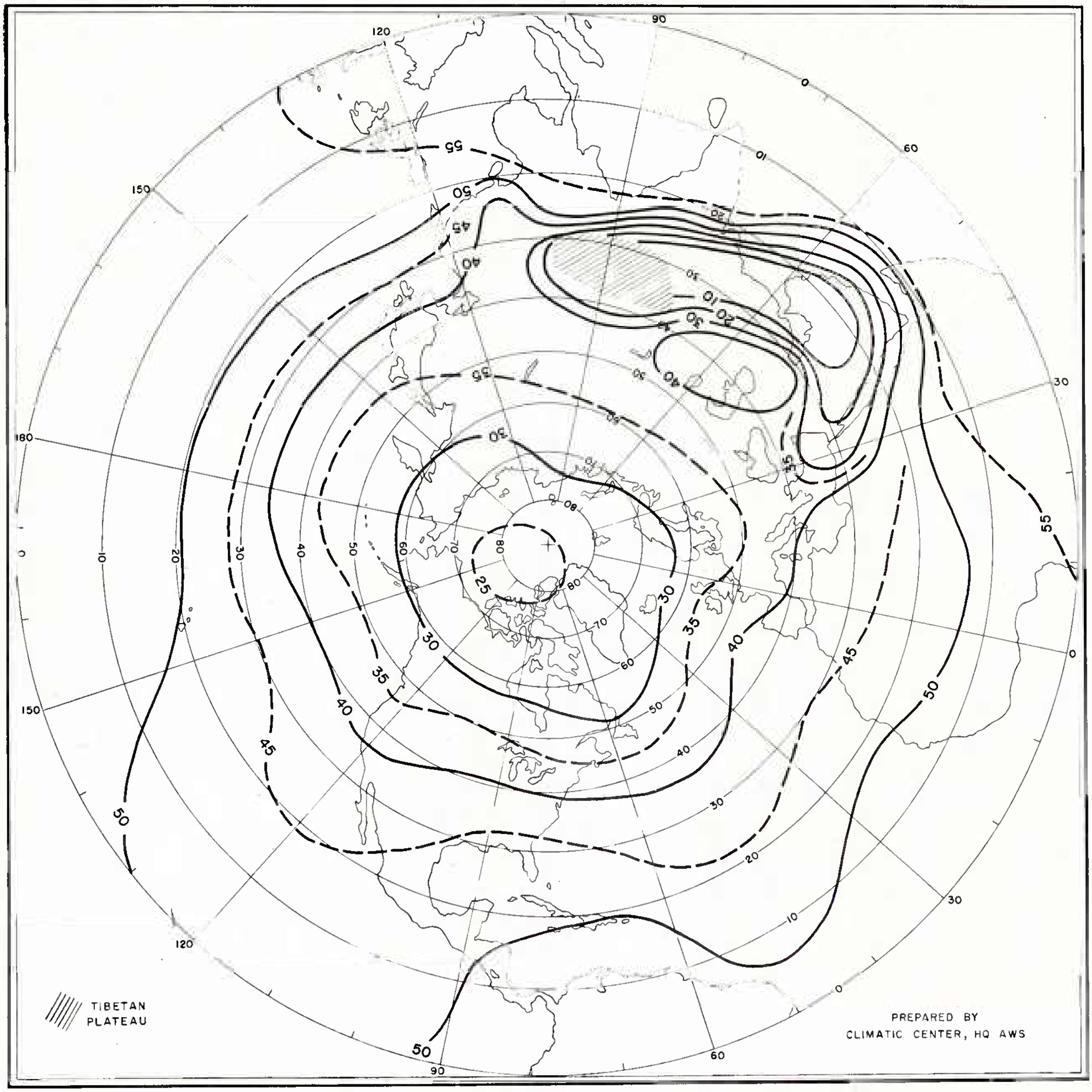

FIGURE 13.. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 95% PROBABILITY OF HAVING < 1/10 SKY COVER
OCTOBER

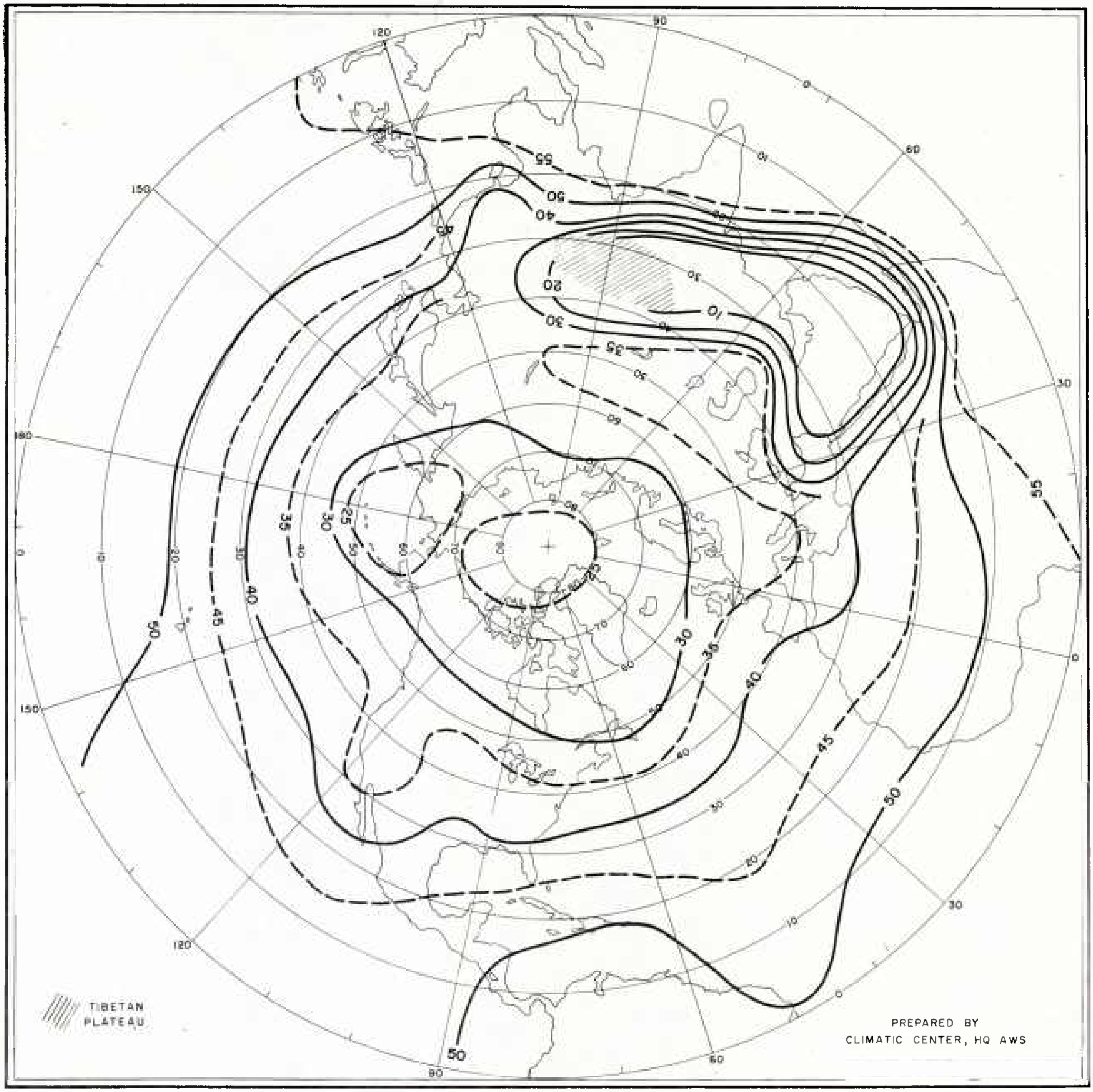

FIGURE 14. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 90% PROBABILITY OF HAVING < 1/10 SKY COVER
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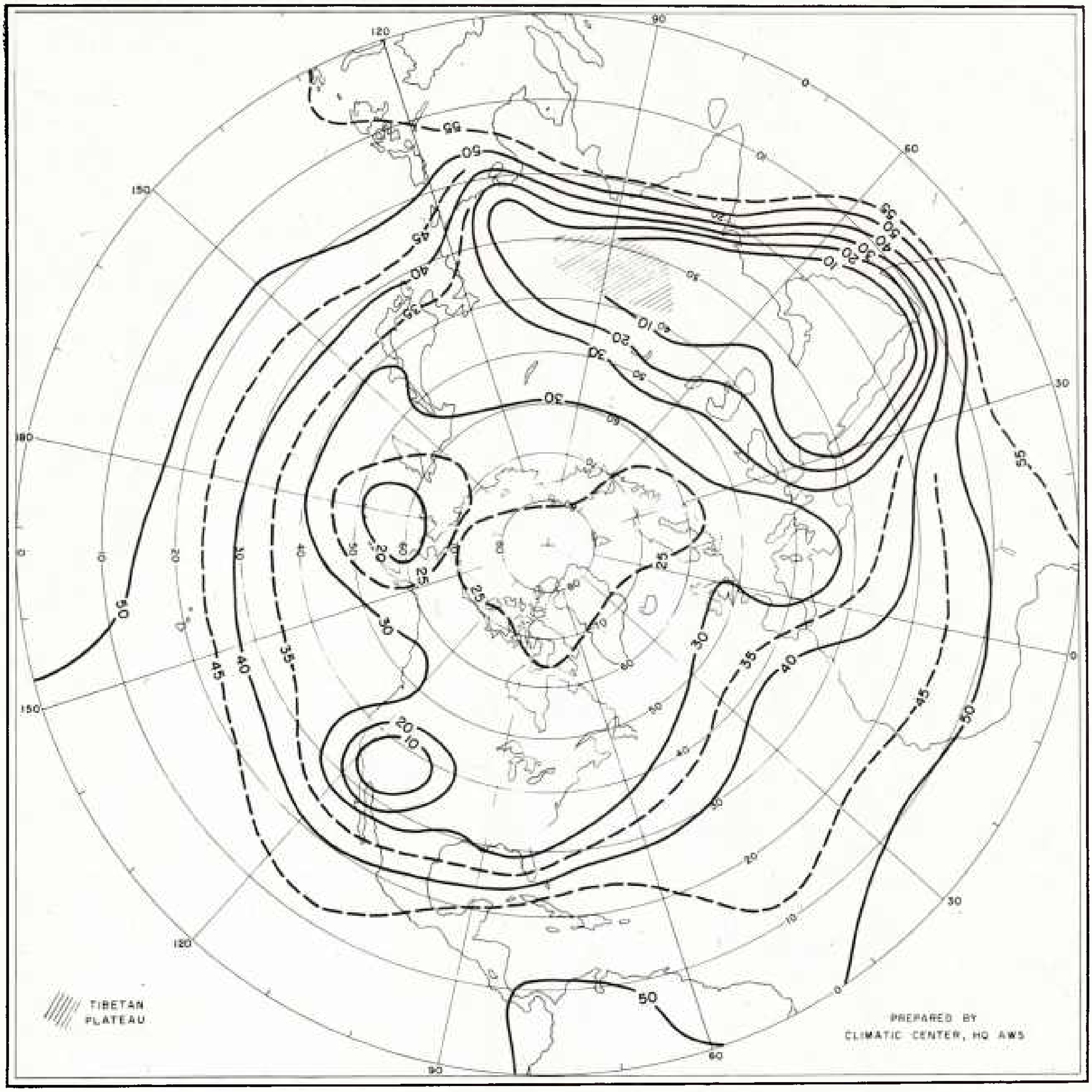

FIGURE 15.. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 80% PROBABILITY OF HAVING < 1/10 SKY COVER
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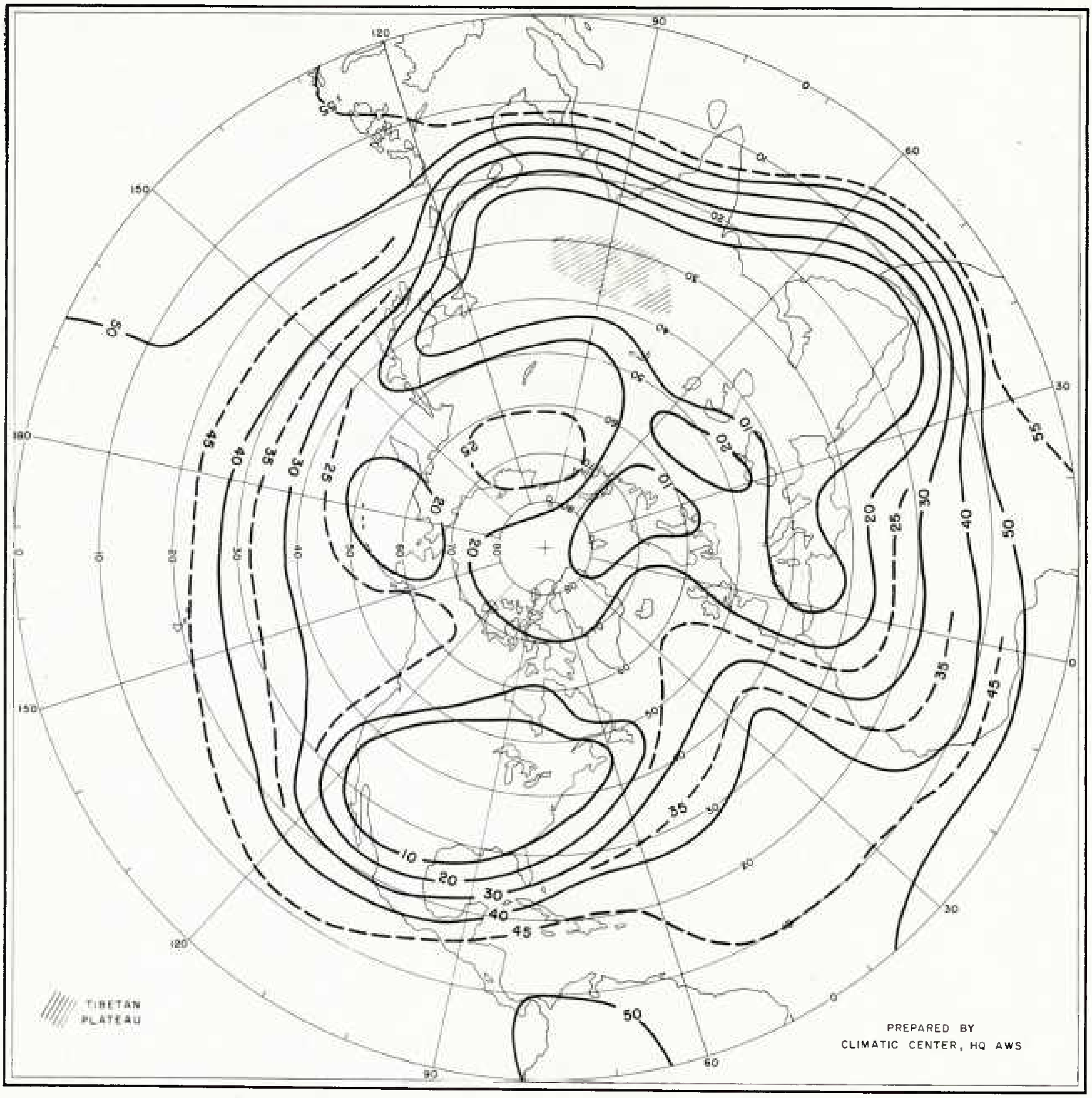

FIGURE 16. ALTITUDES (THSDS OF FT MSL) ABOVE WHICH THERE IS 60% PROBABILITY OF HAVING < 1/10 SKY COVER
OCTOBER

SECTION E — REFERENCES

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